Exploring Offence Statistics in Stockholm City Using Spatial Analysis Tools

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The objective of this article is to investigate changes since the early 1980s in offence patterns for residential burglary, theft of and from cars, and vandalism in Stockholm City using methods from spatial statistics. The findings of previous Swedish studies on crime patterns and the insights provided by different theories, notably one propounded by Wikström (1991), provide a background for this study and are briefly reviewed. The analytical elements of the article are presented in two main parts. The first consists of a brief description of methodological procedures to obtain robust estimates of small-area standardized offence ratios. Attention is paid to both the spatial framework and the method of calculating rates. Standardized offence ratios (SORs) are calculated and mapped using GIS, and the Getis-Ord statistic is used to identify areas of raised incidence. The variation in a relative risk is modeled as a function of socioeconomic variables using the linear regression model, recognizing the complications raised by the spatial nature of the data. Results suggest that while there have been no dramatic changes in the geographies of these offences in Stockholm City during the last decade, there have been some shifts both in geographical patterns and in their association with underlying socioeconomic conditions. *Key Words: Getis-Ord statistic, offence rates, region-building, relative risk, spatial regression.*

In the early 1980s, data on offences for Stockholm showed a rather strong concentration in the inner city for some, though not all, offences (Wikström 1991). Vandalism in public areas and theft of and from cars showed a marked concentration in the inner city, at least in certain parts of it. Although residential burglaries tended to have the highest rates in some outer-city wards, half of all residential burglaries still happened in inner-city wards. Studies in the United Kingdom and the United States, reviewed in Bottoms and Wiles (1997), revealed similar findings. The question is, to what extent have the patterns of these offences changed during the last ten to fifteen years, and what are the socioeconomic variables that underlie current geographies of crime in Stockholm?

It is time to look again at the geography of these offences, for two reasons. First, many cities are undergoing fundamental economic and social changes associated with the shift from modernity (the social formations that emerged out of industrialization) to "late modernity" (Giddens 1990, 1991) or the emergence of the "informational society" (Castells 1989), the "network society" (Castells 1996), or what Hall (1999) calls, in general terms, the "forces shaping contemporary urban Europe." These changes take the form of changes to the built form and land use within a city, as well as to its demography and socioeconomic composition. These changes, and in particular their geography, will affect crime patterns by their impact on the routine activities of offenders and victims. They generate new opportunities for offenders in the forms of new targets where offences may be committed and new patterns of interaction between motivated offenders and their victims. However, there is still little knowledge about how these changes are affecting the geography of offences in cities and "there are surprisingly few studies of crime in the city that can be used for comparative purposes" (Bottoms and Wiles 1995, 44).

The second reason concerns the advent of new technologies for data storage and analysis. The advent of computerized mapping systems as part of police command and control systems has led to the creation of systems for visualizing the growing amounts of geocoded crime data. These are already in use in many police forces in Sweden, the U.K., the U.S., and elsewhere for both operational and strategic purposes (Goldsmith et al. 2000). In addition, geographic information systems (GIS) are making geographical analyses of crime data more penetrating than they were in the past. GIS facilitates the integration of many types of data into a common spatial framework, and opens up the possibility for fine-grained spatial analysis (Heywood, Hall, and Redhead 1992; Block 1995a; Harries 1995; Hirschfield, Brown, and Todd 1995; Lewin and Morison 1995; Ceccato 1998; Wiles and Costello 2000). The value of GIS for analyz-

Annals of the Association of American Geographers, 92(1), 2002, pp. 29–51

Published by Blackwell Publishing, 350 Main Street, Malden, MA 02148, and 108 Cowley Road, Oxford, OX4 1JF, UK.

ing crime patterns becomes even greater when GIS is enhanced with spatial statistical techniques (Block 1995b; Canter 1995; Messner et al. 1999; Craglia, Haining, and Wiles 2000).

This article aims to investigate actual changes in offence patterns in Stockholm City, and in so doing to demonstrate the application of spatial statistics to problems in environmental criminology. Data on three types of offences—residential burglary, theft of and from cars, and vandalism—are analyzed. These offences have been chosen for the following reasons. First, more than 50 percent of police records for Stockholm County involve thefts and vandalism. Vandalism almost doubled between 1990 and 1998, accounting for 14 percent of all recorded offences in 1998 (Jacobson 1999). Second, data on car theft and residential burglary are quite accurate in Sweden, since insurance companies require police records before paying compensation. Finally, residential burglary, theft of and from cars, and vandalism are offences on which there is a broad and rich literature concerning their spatial patterns in different countries and contexts. Some changes in the geographies of these patterns might be expected as a consequence of the wider societal changes noted above.

The spatial analysis of offence data in this study is undertaken with several objectives in mind. The first is to propose a methodology for constructing reliable maps of relative risk for the three offences, and to implement it in the case of the Stockholm offence data. Relative risk provides a measure of the excess risk of being a victim of an offence in an area. In this article, "relativity" is defined with respect to the city-wide average, so that the maps only provide evidence on geographical variation within Stockholm City. The second is to locate statistically significant clusters for the three types of offences. The identification of local offence clusters can shed light on the correlates of crime, and perhaps even on the reasons why certain areas become targets for crime, information that may not be apparent from "global" or "whole map" statistics (Anselin 1995). The third is to investigate the extent to which socioeconomic variables can explain overall patterns of the three offences for Stockholm City. A final objective is to make a comparative assessment of the findings reported here and earlier results on crime geographies in Stockholm, particularly those described by Wikström (1991). However, any comparison with the findings of previous research must be viewed with caution, because the spatial framework and crime classifications used are not exactly the same. In this analysis, "vandalism" included all types of vandalism against private property and also vandalism in public spaces. In Wikström (1991), only vandalism in public spaces was taken into account. Wikström also separated burglaries in cellars and attics from burglaries in residences. Furthermore, changes in the organization of the police authority and in the law have also influenced the statistics (Jacobson 1999).

This article is structured as follows. Section two contains a brief review of the relevant criminology literature, including an examination of how changing urban geographies can induce changes to crime patterns. Section three describes the methodology and presents results on relative risk rates and the presence of significant clusters for the three types of offences. Section four analyzes the relationship between crime patterns and socioeconomic variables and reports the results, comparing our findings with those obtained by Wikström (1991). Finally, section five discusses directions for future work.

Local Geographies of Crime and Processes of Change

The first subsection below identifies the macroscale processes of economic and social change that are believed to have impacted on the geography of crime at the end of the twentieth century. The next three subsections review findings from studies, mostly conducted in the 1980s, on the geography of the three offences, with an emphasis on studies of Stockholm. The final subsection discusses how the playing out of macroscale processes in Stockholm might be expected to have affected its offence patterns, and attempts to identify a broad set of expectations regarding current offence patterns in Stockholm and how they might be expected to differ from those in the 1980s.

Local Geographies of Crime: Macroprocesses of Change

Wikström (1991) provides the theoretical framework for this study of offence patterns, represented in Figure 1. Wikström's model provides a basis for understanding the geographical distribution of offences at any given time. The starting point for the model is the distribution of land use within a city. Land use determines both the activities found in an area and the composition of the population at any given time. The land use of an area of the city affects the number of interactions that take place between offenders and potential victims in that area. Spatial variation in land use affects spatial variation in the number of interactions that are criminologically relevant in the sense that they could lead to offences. The identification of criminologically relevant interactions

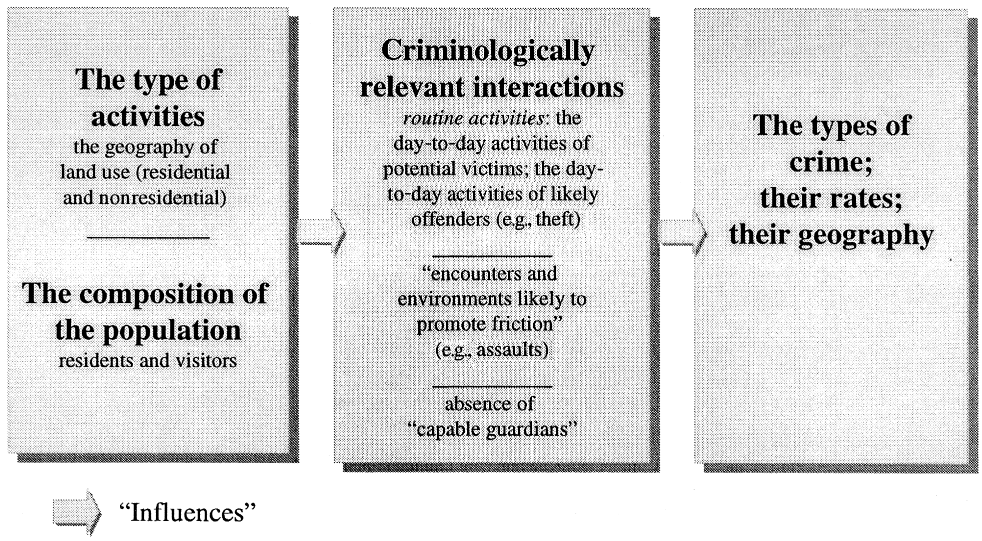

Figure 1. Wikström's (1991) model.

rests on specifying the routine activities of offenders and victims that generate "suitable targets" (Cohen and Felson 1979) and the spatial awareness of offenders, in particular their cognitive awareness of criminal opportunities (Brantingham and Brantingham 1981). In brief, offences occur where criminal opportunities intersect with areas that are cognitively known by the offender, which in turn are influenced by land-use patterns. Bottoms and Wiles (1997) provide a review and critique of Wikström's model.

The analysis of crime patterns at any one point in time takes land use as a given, but over time land-use patterns may change. Within the framework provided by Wikström (1991), land-use change provides an important underpinning of any explanation of how offence patterns might change. Similarly, over time, perhaps partly as a consequence of land-use change inducing new patterns of movement but also as a consequence of wider changes within society, there may be shifts in the routine activities of the general population as well as shifts in offenders' cognitive awareness of different places. We now consider, therefore, the wider changes associated with the societal transition to late modernity, which may induce changes in the intraurban geography of offences. We focus on the effects of economic and social change.

Economic change brings about changes in cities in terms of land use, demography and socioeconomic conditions. This is often associated with increasing levels of insecurity that legitimize the creation of "security bubbles" such as well-protected leisure centers and gated residential areas (Bottoms and Wiles 1997). These sites are deliberate attempts to restore the sense of security that has supposedly been lost. Another example is the increase in the number of large outlets or shopping areas on the outskirts of cities. Although shopping malls with their own security systems provide a protected and defended locale for work, consumption, and leisure activities, they also create new sites for offences. People who are mobile may prefer the service outlet most convenient to their workplace, instead of using the services near where they live. This leads to the decline of small local shops and hence to the elimination of these locales as sites for offences. Thus, economic change not only eliminates certain sites where offences might occur but also produces new sites (albeit well-protected ones, in some cases), new opportunities, and, hence, new patterns of offences. In addition, economic change produces new patterns of mobility associated with changes in land-use patterns both of would-be offenders and of potential victims. Increasing affluence among certain groups leads to new patterns of routine activity. Both of these create new opportunities for crime and hence new geographies of crime in the context of Wikström's (1991) model.

Social change has seen the emergence of a new geography of social differentiation linked to an increased economic polarization, which contrasts, for example, those with relatively secure, well-paid jobs with those affected by the decline of traditional manufacturing employment or by the consequences of technological change. These effects may be compounded by the operation of public- and private-sector housing markets that effectively concentrate the latter group of people in certain areas of the city. This, in turn, may lead to the emergence of areas that compound social exclusion with a particular local culture and social organization that may lead to high levels of crime within those neighborhoods. The loss of social cohesion and other forms of social capital in certain working-class neighborhoods can have a significant effect on crime levels and the types of crime committed (Hirschfield and Bowers 1997). Such social and economic polarization is apparent in so-called global cities (Sassen 1991) and, in other types of urban areas such as the "dual city" (Mollenkopf and Castells 1991; Dangschat 1994; Van Kempen 1994), or with a modified content of the "Quartered City" (Marcuse 1993) or even the "city of the coming Golden Age" (Hall 1999).

Other macroscale changes also have an impact on local geographies of crime. Two of these comprise two contrasting processes. The first relates to the increasing demand for and production of a homogenized culture. Evidence of a homogenization of space is found, for example, in standardized forms of architecture across Europe and in airports, entertainment centers, and shopping areas. The functionality of some forms of architecture tends to suppress local cultural codes. It contributes to the creation of a "space of flows" (Castells 1996), which attends to the needs of mobile social groups that must travel as part of their work and have more leisure time to travel and to consume than ever before. Among European Community member countries, investments in infrastructure, especially in international transportation links, were one of the priorities during the 1990s in order to promote social cohesion, diminish the economic disparities between countries (EC 1997, 1998), and improve the connections between European capitals. This increase in accessibility makes cities, regions, and countries more vulnerable to crime, since new patterns of mobility may induce new offence patterns. At the intraurban level, these macroscale changes may generate new patterns of offences by creating new sites for offending and new transient groups unfamiliar with the levels and types of risks in particular areas. Another example of this macroscale change relates to new lifestyles imposed by recent technological developments. People become less attached to—less committed to—local areas and communities. This may lead to a decrease in capable guardians at the local level, and thus increase the areas vulnerability to crime. On the other hand, telecommuting may induce behaviors that go in the opposite direction, resulting in fewer trips to the workplace and more time spent in the residential areas, resulting in potentially more "capable guardians" and therefore less crime.

The second process envisages the re-emergence of local cultures as a counterreaction to such homogenization, "global disorder and uncontrollable, fast-paced changes" (Castells 1997, 64). It involves a simultaneous embracing of the new and the traditional. According to Featherstone (1993), globalization does not produce homogeneity but familiarizes us with greater diversity. Ethnic festivals (e.g., Rinkeby in Stockholm, Notting Hill in London), "multicultural tourism" (Bergsrud 1999), and tourism directed towards local consumers (e.g., carnivals that promote the urban cultural heritage) provide examples of the activities that are emerging as a result of this search for local identity and self-worth. This leads to a new market for local cultures, which in turn produces "new consumption landscapes" (Sýkora 1994, 1153). This, in turn, affects the level, structure, and geography of crime through the creation of new sites for offending, new patterns of interaction, new environments that might engender friction, and new groups of potential victims. Bottoms and Wiles (1995, 1997) discuss these processes of economic and social change and other examples of their implications for the study of crime patterns at the local level.

Since the work of the Chicago School, many explanations have been offered for particular offence geographies. The British and American traditions of spatial analysis of crime data have continued to reveal strong associations between characteristics of urban areas and the locations of certain types of offences. In the following sections, we consider the three offences under investigation here.

Local Geographies of Vandalism

Roos (1986) explored the reasons behind reported vandalism, comparing two urban areas in Sweden: a small town (Arvika) and a large city (Malmö). The differences recorded in this study between large-city vandalism and small-town vandalism showed, among other things, that segregation in the housing market, form of tenancy, and demographic structure are not significant in explaining vandalism in small urban areas. In Malmö, levels of vandalism showed a positive correlation with a high population turnover, a high percentage of multifamily houses (flats in multistory buildings), a high percentage of unemployed people, a high percentage of households receiving social benefits, and a high percentage of foreigners and low-income workers.

Wikström (1991) analyzed the occurrence of vandalism—meaning illegal destruction of property in streets and squares and on public transport—in public places in Stockholm (Figure 2). Multiple regression analysis was used to explain patterns of offences. Wikström showed that variation within the inner city in rates of vandalism were closely associated with area variation in the location of places of public entertainment. For the outer city, Wikström found that a significant proportion of the spatial variation in vandalism was related to social problems or disorganization. Results for Stockholm City have

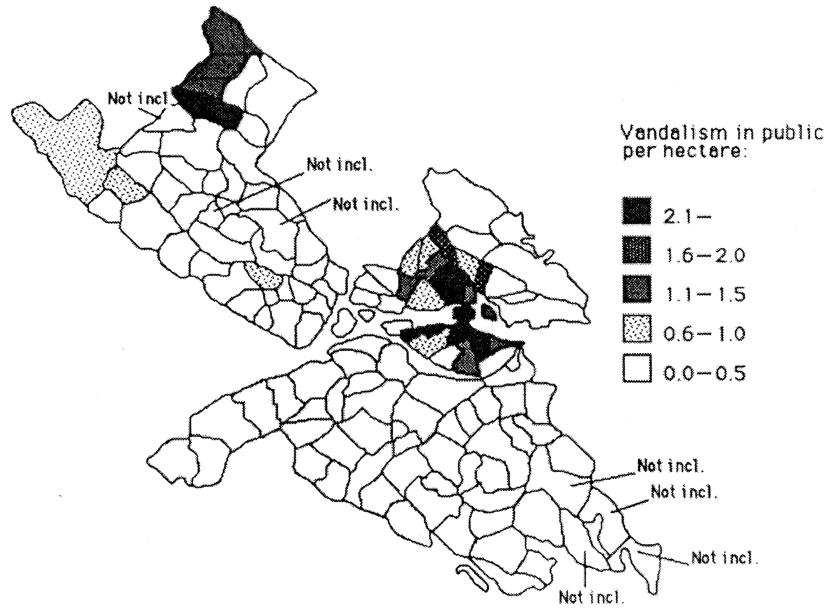

Figure 2. Vandalism in public per hectare in Stockholm, 1982. *Source:* Wikström (1991, 204).

shown that stores in areas with a low degree of social stability were more exposed to various kinds of offences, including vandalism, than were stores in other areas (Torstensson 1994).

The Swedish experience may differ from that of other countries. Evans (1992) reviewed U.K. research that showed correlations between housing ownership, income, and vandalism. The Islington Crime Survey (Maclean, Jones, and Young 1986), for instance, showed that the highest income earners experienced the highest rates of vandalism. In other studies cited by Evans, the areas of highest risk were those with high levels of owner-occupied housing, regardless of whether they were inner city areas.

Local Geographies of Theft of and from Cars

In Sweden, most car-related thefts occur when cars are parked on the street, usually near the owners' homes. In Stockholm, Wikström (1991) found area variation in thefts of and from cars to be strongly related to area variation in violence and vandalism in public. The highest rates were found in the city center of Stockholm or areas near it (Figure 3). The distribution for the suburban areas showed that rates of thefts of and from cars there tended to be highest in areas with social problems, predominantly in areas with flats in multistory houses. These may be the areas where the offenders reside or tend to spend time.

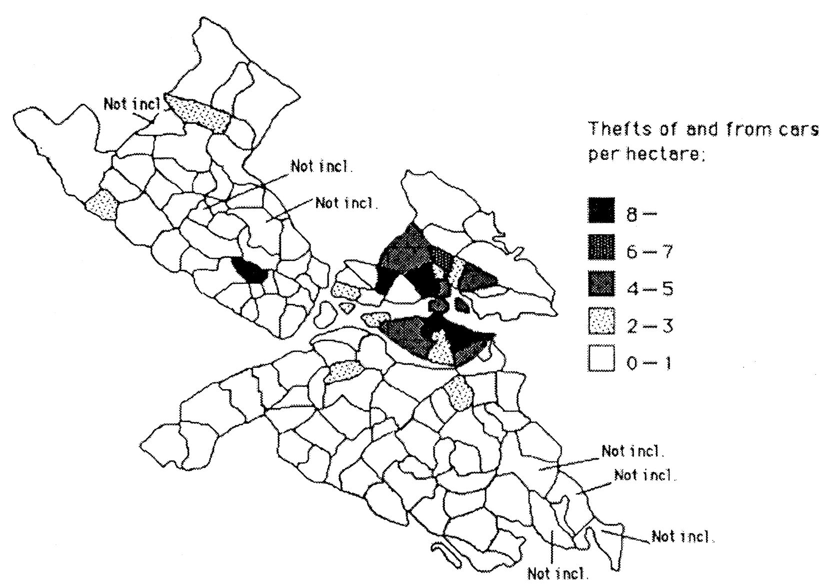

Figure 3. Thefts of and from cars per hectare in Stockholm, 1982. *Source:* Wikström (1991, 206).

This finding in Stockholm corresponds with findings elsewhere. Evans (1992) reported empirical findings that indicated a relationship between car-related thefts and low economic status. Residents of inner cities, flats, and maisonettes and council tenants are most at risk from theft of and from cars in British cities.

Local Geographies of Residential Burglary

Wikström (1991) showed that residential burglaries in Stockholm (excluding those in attics and cellars) tend to occur mostly in some outer city wards of high socioeconomic status (i.e., with single-family houses), especially in districts near high offender-rate areas (Figure 4). This finding is consistent with the observation that most offenders come from socially disadvantaged areas and tend to commit crimes close to home that lie within their routine activity paths.

While not unique in the literature, this finding suggests a different geography for the crime of burglary in Sweden than in other countries. Evans (1992) pointed out that poor households are more at risk from residential burglary, although within poor areas, higher-value properties may be more at risk from residential burglary, since these constitute a more attractive target than nearby houses. In their study of residential burglary in Great Britain, Maguire and Bennet (1982) indicated that within sizeable towns, those living in poorer housing areas are the most vulnerable, especially if the areas are close to the town center. Pockets of particularly affluent middle-class housing on the outskirts of towns sometimes receive a disproportionate amount of attention from burglars, and middle-class housing located on or very close to main roads is also more likely to be burgled than similar housing that is less directly accessible to passers-by. Their findings also indicated some relationship between housing type and vulnerability to burglary. Both small and large detached houses are generally more vulnerable than semidetached or terraced houses. Herbert's (1982) study of residential crime (residential burglary and thefts from dwellings) in West Swansea showed that the vulnerable areas occurred in the heterogeneous inner city and in some of the large public sector estates, not in wealthier suburbs.

In the case of Sheffield, Wiles and Costello (2000) found that domestic burglary and criminal damage is a very concentrated phenomenon. They showed that the residential areas with high offence and victimization rates are generally found on poorer housing estates and in some socially mixed city areas. This pattern holds for several reasons. First, even poor areas contain plenty of suitable targets, such as videos, televisions, and cars. Second, offenders tend to live in these areas and, on the whole, tend to offend close to home rather than conduct long-range instrumental searches across a city. Third, if offending is carried out away from home, it is often in areas where offenders have contacts, not unknown middle-class parts of the city.

Macroscale Processes and Changes to the Geography of Offence Patterns in Stockholm

The first subsection above showed that there is a lack of specificity as to how the macroscale processes of late modernity affect crime patterns. Using the framework provided by Wikström's (1991) model, we now discuss

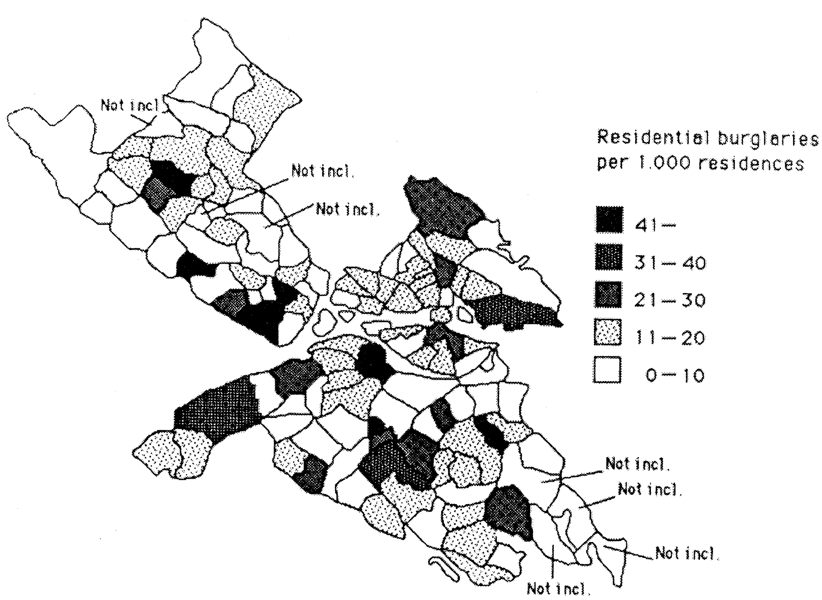

Figure 4. Residential burglaries per 1000 residences in Stockholm, 1982. *Source:* Wikström (1991, 205).

how the geographical patterns for the three studied offences for Stockholm might be *expected* to have changed since the early 1980s. We start by briefly discussing aspects of the changing socioeconomic urban geography of Stockholm.

Stockholm is the capital and biggest city of Sweden. In 1998, the city of Stockholm had over 720,000 inhabitants in 1998, and the Greater Stockholm area had over 1.6 million inhabitants. We limited our case-study area to the city of Stockholm, which means the inner-city area and those suburbs belonging to the city of Stockholm.

Compared to other Swedish cities, Stockholm City has a very high population density of 1300 inhabitants/km^2. However, only a few areas of the inner city are densely populated. Between 1950 and 1985, the inner city area lost nearly 200,000 inhabitants. This decrease in population can be partly explained by the conversion of building space into offices at the same time as the population moved out towards new residential areas in the neighboring municipalities. However, the demand for apartments within Stockholm City during the last decade has created a need for building companies to make as many apartments as possible available by renewing old residential areas and building new ones, mostly in vacant or old industrial zones. In Stockholm City, about 90 percent of dwellings are multifamily houses; the rest are single-family houses. Two out of three dwellings are rented; almost all the rest is tenant-owned housing. In contrast to many British and North American cities, there are no residential slums or run-down residential areas in the inner city or elsewhere in Stockholm.

Because of its particular characteristics, the city's center is highly vulnerable to acts of vandalism. Located in the southern area of the inner city, the central business district (CBD) is characterized by many office buildings and a number of large department stores. The governmental and ministerial buildings are located in this area, as are the major shopping area of the city, theatres, museums, restaurants, bars, and cinemas. The main public transport junction is located in the CBD area. All underground lines pass through the Central Station, which is the main railway station of the capital, making this area a place through which many travelers and workers pass every day. Segerls torg, a central square and one of the main meeting points of the city, contains a lot of people during the entire day, including youths and drug addicts who frequent the square and the surrounding streets.

As with many other European capital cities, Stockholm has been undergoing fundamental economic and social changes. Anjou (1998) points out that during 1990–1997, the total population of Stockholm City increased at the same time as the total number of jobs decreased. Traditionally, the region has had a net in-migration of young people aged between 20 and 30 and foreign citizens. About 20 percent of the city's population was born abroad, 50 percent of whom became Swedish citizens. During 1990–1997, the unemployment rate also shifted, from 1 percent to 7.3 percent. An increase in dependence on social benefits among single-person households, young people, and foreign households has also been noted (SOU 1999, 46).

In Stockholm, as in other large cities, immigrants are primarily concentrated in areas with low socioeconomic status in which rental tenancy is dominant. Thus, there is a clear connection between socioeconomic conditions, type of tenancy, housing type, and ethnic composition (Vogel 1992; USK 1996; Bevelander, Carlsson, and Rojas 1997). Geographical, ethnic, and socioeconomic segregation has increased during the last decade (RTK 2000) as a result of, among other things, a decrease in income and income mobility (Sandström 1997; SOU 1998, 25). In Stockholm City, evidence exists of changes in the geography of income levels between the 1980s and 1990s (Figure 5).

While certain areas, especially in the south, have become impoverished, the average income levels have increased in other residential areas, mostly close to the city center. There are indications that a gentrification process is taking place near the city center, of which Södermalm is a good example (see Figure 5). In Stockholm, as in other European cities such as Rome and Madrid, the exclusive residential areas tend—as pointed out by Castells (1996)—to appropriate urban culture and history and to be located in refurbished or well-preserved areas of the central city. Vogel (1992, 154) pointed out that "the wave of rebuilding in the central areas of the metropolitan areas in Sweden reinforced residential segregation." It is also worth noting that areas such as Skärholmen, Sätra, Rinkeby, Tensta are examples of low-income areas in the 1980s that remained low-income areas in the 1990s. The same can be said about other parts of the city that were characterized by having high income levels and continue to have them—for example, Västerled and the traditional areas in the city core. RTK (2000) confirms this strong tendency for economic polarization among social groups in the 1980s and 1990s for the whole of Stockholm County.

Despite these socioeconomic changes, the total number of recorded offences is not higher in 1998 than it was in 1990; nonetheless, people feel less safe than before (Jacobson 1999). Ivarsson (1997) estimates that one-fourth of Stockholm's population is often or always afraid of going out by themselves in the neighborhood in which they live when it is dark. This may indicate that there

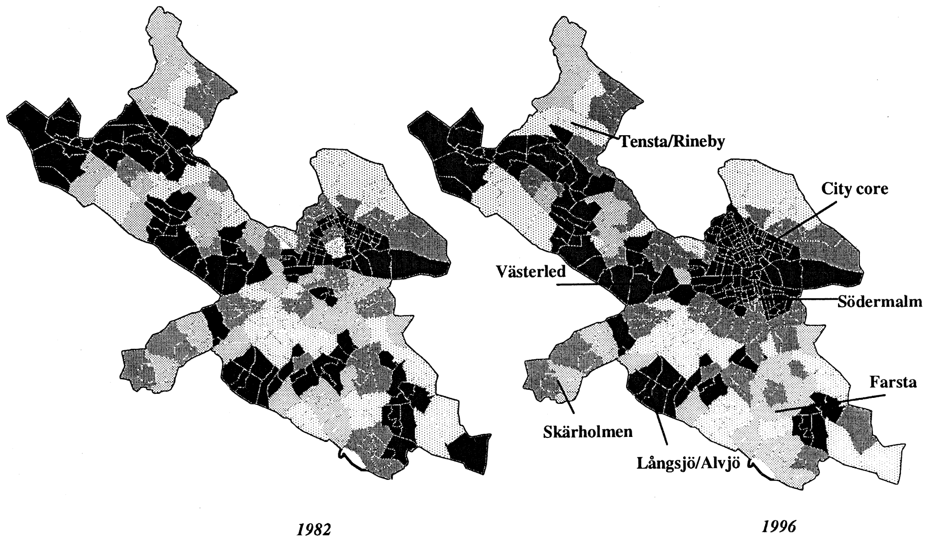

Figure 5. Average income levels (active population age 16–64) in Stockholm City in 1982 and 1996. The darkest patterns indicate the highest-income levels. *Source:* Based on maps by USK (1999).

have been changes in offence type, with significant increases in violent offences (e.g., assault and rape) and vandalism. The latter almost doubled between 1990 and 1998 for Stockholm County (Figure 6).

We expect that certain types of offences will have changed their geography more than other types. The geography for vandalism and car-related thefts is expected to continue to show high levels in the inner city area. This is because these offences seem still to depend on the sorts of activities found in the CBD, such as office employment and public entertainment. These activities have not changed their location within Stockholm a great deal since the 1980s. On the contrary, there is some evidence of additional concentration in the inner city (e.g., the locations of the headquarters of new internet technology [IT] firms). However, new areas of high crime incidence are expected to appear on the outskirts of the city. These arise for two reasons: they are associated with the deprived areas or so-called problem areas (*Problem områden*), the number of which increased during the 1990s; and people are more mobile, which creates new opportunities for offenders.

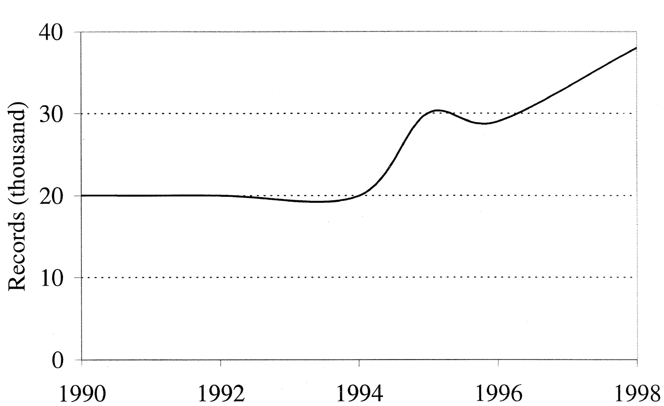

Figure 6. Recorded vandalism in Stockholm County, 1990–1998. *Source:* Based on Jacobson (1999, 27).

The increasing process of economic polarization, followed by a spatial and economic fragmentation of the city, is also expected to affect the geography of residential burglaries. Wealthy areas tend to become more geographically and physically isolated from the rest of the city; in so doing, they become more attractive targets for burglary. In Stockholm, the Hammarby sjöstad's project is a good example of such a development. This building project, with 8,000 apartments in Southern Stockholm, was planned to test urban planning's role in preventing urban crime. The creation of such safety redoubts reinforces segregation patterns, since not everyone can afford to live in these safe areas. While the creation of such buildings might displace some crime to other areas, their presence could represent an attractive target to an offender, regardless of the level of surveillance. Finally, increasing levels of geographical segregation may increase the likelihood that certain groups will offend, which may result in greater interarea variation in offending rates. Liljeholm (1999) describes the geography of teenage offending in Stockholm by city parish.

Linking these local changes to the key elements of Wikström's model leads to the expectation of a generally more scattered spatial pattern for all three offences, with less concentration in the inner city area in the mid- to late 1990s compared to the early 1980s. This general trend is associated mostly with an increasing geographical and economic segregation of the population, combined with changes in land use in the most peripheral areas. This includes the emergence of large out-of-center shopping areas and other types of retail outlets. Increasing levels of population mobility of both potential victims and motivated offenders may also contribute to this dispersal by tending to increase the number of criminologically relevant interactions in a larger number of areas of the city.

Methodological Procedures and Analysis of Rates

The statistical dataset of offences used in this study of Stockholm City was extracted from the Police Authority of Stockholm County's (1998) database. The data, which refer to 1998, were initially divided by offence type and geographical unit, *basområde*, varying in population size from less than 300 to 8536 inhabitants. In general, each of Stockholm's basområde has a common housing type, which reflects different stages in the city's expansion.

The socioeconomic data were obtained from the Stockholm Office of Research and Statistics (Utrednings- och Statistik Kontoret—USK) using the same geographical units. Unfortunately, these statistics were not all available for the same years. The statistics for households come from the beginning of the 1990s. Statistics for unemployment among the population come from 1998. Table 1 shows a description of the data set used in the study. For further detail on the dataset, see Appendix 1.

Creating Reliable Maps of Standardized Offence Ratios

The methodology adopted here involved two stages: first, the creation of a spatial framework that merged spatial units with small populations into larger aggregations; and second, the manipulation of the rates themselves using a Bayesian methodology. The aim is to construct reliable maps of the variation in relative risk for different types of offences across Stockholm City.

Constructing a New Regional Framework. A common problem with area-based analysis is that the results of analysis are sensitive to the choice of spatial unit (Wise, Haining, and Ma 1997). There are several reasons why it is often beneficial to group the basic spatial units to form larger regions as the framework for the analysis. First, doing so increases the base population in each area, so that offence rates can be computed from a larger denominator. Aggregating small regions or merging them into larger units results in rates that are more robust to within-area variation in the number of cases that may arise from random variation in the occurrence of crime events. Second, grouping the basic spatial units reduces the effect of suspected inaccuracies in the data. Especially with small areas, an error of one or two in the count of offences could have a large effect on the calculated rates, where such errors may have less effect for larger areas. Finally, doing this kind of grouping facilitates attempts to reduce the effect of suspected inaccuracies in the location of offences. Using larger units essentially means that a smaller proportion of the cases are near boundaries, and hence a smaller proportion are likely to be assigned to the wrong unit as a result of geocoding errors. This is particularly important for crime statistics, because there are problems of reliability regarding not only when the offence occurred but also where it took

Table 1. Characteristics of the Dataset

Type of Data	Description	Year	Source
Offence			
Residential burglary	Theft and theft followed by burglary (codes[a] 0824, 0825, 0826, 0858, and 0859). This includes attic and cellar theft.	1998	Police Authority
Theft of and from cars	Theft of and from cars (codes[a] 0801, 0802, and 0840)	1998	
Vandalism	Damages, disturbance, and graffiti (codes[a] 1201, 1202, 1205, 1203, 1207)	1998	
Socioeconomic			
Population	Total number of inhabitants	1997	USK
Born abroad	Total number of inhabitants born abroad	1997	
Unemployment	Total number of unemployed inhabitants aged 18–64.	1998	
Income	Average income (inhabitants aged 16–64) by geographical unity	1996	
Residential turnover	Total number of inhabitants who move into and out by geographical unity	1996–97	
Total households	Total number of households	1990	
Housing by type	Total number of single and multifamily houses	1990	
Percentage of households receiving social benefits	Number of households with dependants on social benefits	1995	

[a] *Source:* Statistiska Centralbyrån (Statistics Sweden) 1994.

place. In addition, the location of an offence may be incompletely registered in Sweden, which adds to the difficulty of creating reliable maps.

The method used was a region-building module implemented in the SAGE software system (Haining, Wise, and Ma 1996; Wise, Haining, and Ma 1997; Haining, Wise, and Ma 2000; see Appendix 2 of this article). The region-building module classifies *N* objects (areas) into K groups (regions) using the K-means method. The method requires two basic elements: an initial partition with K groups from *N* objects, and a combined objective function that measures whether one partition is better than another. Up to three criteria—homogeneity, compactness, and equality—can be introduced into the objective function to construct regions.

Although Stockholm is an archipelago, no major statistical problems are expected from the lack of contiguity of the zones of the study area. First, only a small part of the central area is physically disconnected from the rest of the city (central islands are separated by water bodies). Second, the central unit functions like adjacent zones, and these areas are easily accessible from the rest of the city by modern transportation links, mostly because they are part of the inner city.

One hundred and nineteen new spatial units were created for Stockholm City from the original 350. Of the three criteria available in the SAGE module, only the equality criterion was invoked to build the new spatial units. Population size was used as the criterion. This criterion ensures that the population in the new spatial units would be as similar as possible. The number of regions was chosen based on a subjective assessment of what the minimum population ought to be to try to ensure reliable rates. As a result of using the region-building module in SAGE, a new set of regions was created in which the minimum population size was 3,651, the maximum was 10,168, the mean was 6,517 and the standard deviation was 1,547. As Figure 7 shows, ten areas were excluded from the crime analysis because they had extremely low residential populations, so the socioeconomic data for them were missing, and because their locations were at the city's borders.

Rerunning the region-building module yields different outcomes, so it is possible to compare the effects of different runs. Histograms are provided in SAGE in order to assess the success of the method in achieving its objective. Several runs were performed and the partition that came closest to generating truly equal population counts was chosen. The final stage of the process involved the creation of a new set of boundaries by removing the boundaries between zones in the same region and merging their values together using Arcview. Figure 7 illustrates the final set of regions containing the 119 new spatial units.

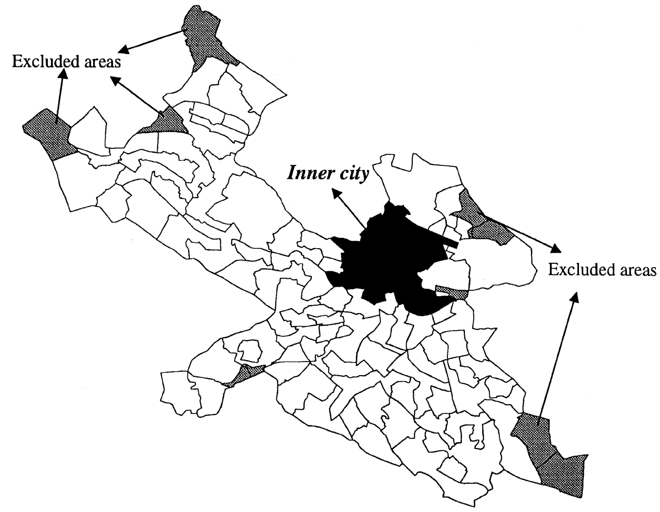

Figure 7. The new spatial units produced using the regionalization process in SAGE. The units that compose the inner city are shown in black.

Bayes-Adjusted Standardized Offence Ratios. In order to have a measure of relative risk of the offences for each of the 119 regions of Stockholm City, a standardized offence ratio (SOR) was calculated using arithmetic functions in SAGE. This type of standardization is a useful way of representing data for a set of areas that differ in size (absolute values would tend to over-emphasize large areal units) and where it is necessary to allow for differences in population characteristics between areas (Haining 1990). The SOR for region *i* is given in the following equation:

$$SOR(i) = [O(i)/E(i)] \times 100 \qquad (1)$$

where $O(i)$ is the observed number of offences of a given type and $E(i)$ is the expected number of offences of a given type.

With sufficiently disaggregated offence data that indicates, say, the housing type at which a burglary was committed, the calculation of the expected count could be undertaken in a similar way to that used, for example, in the calculation of standardized mortality ratios in disease mapping (Kahn 1989). There, it is usual to control for the confounding effects of age and sex in estimating area-specific relative risks. Age of house or housing type could be confounding factors in relation to burglary rates if the aim is to obtain an area-specific measure of relative risk. In this work, however, we simply obtained an average rate for Stockholm City by dividing the total number of offences of a given type by the total size of the chosen denominator. For each area i, this average rate is multiplied by the size of the chosen denominator in area i to yield $E(i)$. For this reason the maps of relative risk are in fact rate maps, as produced by Wikström (1991), divided by a constant that is the average rate for Stockholm City and then multiplied by 100.

It is important to choose a suitable denominator for calculating $E(i)$. Wikström (1991) pointed out the difficulty of defining plausible denominators, which is particularly problematic for mobile targets such as cars. He suggested a list composed of best denominators and those that are practicable (that is, available) for the calculation of city crime rates. For instance, for thefts of and from cars, the best denominator should be the number of cars in an area, while the often-used denominator is the area of the unit. Table 2 shows the denominators used in this study for calculating SORs. The use of area as the denominator could result in higher rates in the inner area. This is because there is likely to be a higher density of roads per unit area in the inner area, and therefore more opportunities for car-related crime—and vandalism—there than in an equivalently sized area in the outer parts of Stockholm.

In mapping relative risks of diseases, it is increasingly becoming the practice to compute Bayes- (or empirical Bayes) adjusted rates to adjust for the effects of population size variability across the map (for details, see, e.g., Clayton and Kaldor 1987; Mollie 1996). The Bayesian approach is a model-based approach to map smoothing. It involves specifying the distribution from which the area-specific relative risks have been drawn. In the case of offence data, the same adjustment process should improve the SOR as a measure of risk variability across the map.

The observed number of offences in area i is assumed to be the realization of a Poisson model with parameter $\lambda(i) = E(i)R(i)$, where $R(i)$ denotes the true (but unobservable) relative risk. The Poisson model is assumed since the risk of any offence is sufficiently rare. The selected model for the population of relative risks, called the prior distribution, is the gamma distribution. The effect of using the gamma distribution for the prior distribution ensures that SORs based on large populations are largely left unadjusted, while SORs based on small populations are shrunk towards the mean for Stockholm City (Clayton and Kaldor 1987). The Bayes-adjusted rates are not strictly standardized offence ratios; instead, they are the posterior means of the relative risks. However, here we will call them Bayes-adjusted SORs.

Table 2. Chosen Denominators for Standardized Offence Ratio (SOR)

Crime	Chosen Denominator
Vandalism	Area unit (e.g., hectare)
Theft of and from cars	Area unit (e.g., hectare)
Residential burglary	Number of households

The gamma distribution is often used for the prior because, compared to other choices of prior distribution (such as, e.g., the log-normal) it does not pull extreme values severely towards the area mean. Since the aim is to identify extreme rates, the gamma distribution appears to represent an appropriate compromise. Selecting the gamma prior means that no allowance is made for spatial correlation in the relative risks $\{R(i)\}$. Other models for the prior, such as the log-normal model, could be specified instead in ways that incorporate spatial structure (Mollie 1996). However, there are at least two reasons why this extension of the Bayesian approach is not appropriate in the present context. First, the introduction of spatial smoothing is most appropriate when the analyst is looking for trends or large-scale patterns in the relative risks. In contrast, the objective here is not to look for broad trends, but to identify areas of raised relative risk. The introduction of a spatial prior would tend to smooth out such areas, particularly if they are geographically isolated. Indeed, the adoption of the Bayesian methodology in the form presented here already means areas with extreme rates; however, small populations will probably not be detected. Second, basområde are small, and, given the heterogeneity of urban space, adjacent areas need not be similar in terms of housing type or other factors that underlie spatial variation in offence rates. It is therefore not necessarily the case that we should expect strong similarity in relative risks between adjacent spatial units.

In the present analysis, quite a close similarity occurs between SORs and Bayes-adjusted SORs, because the process of constructing the new spatial framework has eliminated much of the interregional variation in population. Nonetheless, in the remainder of this article, the Bayes-adjusted SORs are used. We argue that by constructing regions of sufficient population size and using a Bayesian adjustment or borrowing strength methodology, we obtain maps of spatial variation in SORs that are more reliable than if only one or neither of these operations had been performed.

Figures 8, 9, and 10 show the maps of relative risk for the three offences. The first map in each figure identifies all areas where, after Bayes adjustment, $O(I) > E(I)$. The second map in each attempts to follow the mapping scheme of Wikström (1991) by creating intervals that contain the same proportions of areas as found in the corresponding intervals of the Wikström maps.

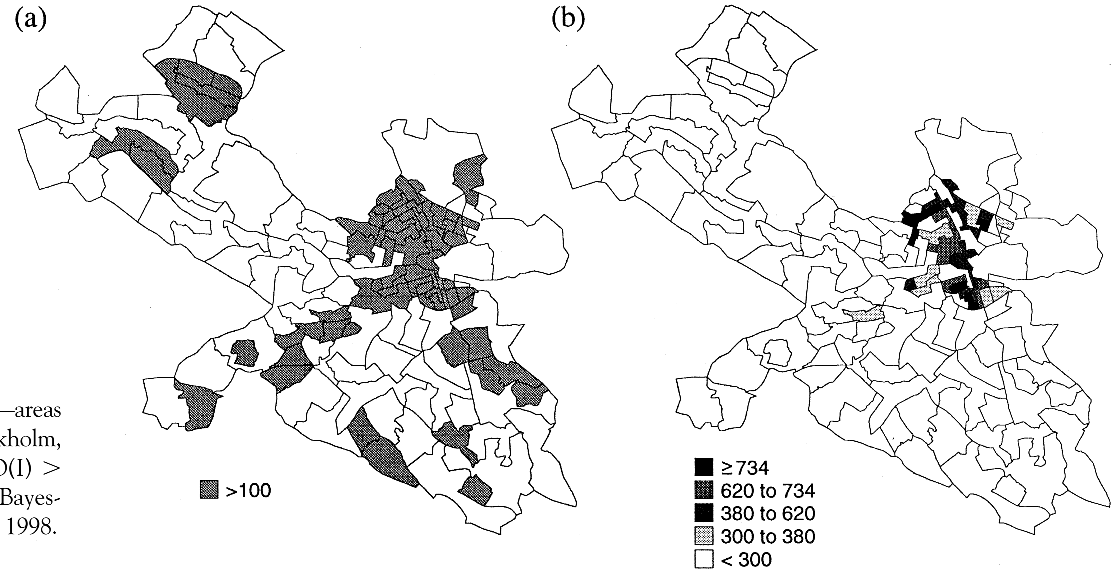

Figure 8. (a) Vandalism—areas with higher risk, Stockholm, 1998, Bayes adjustment O(I) > E(I). (b) Vandalism, Bayes-adjusted SOR, Stockholm, 1998.

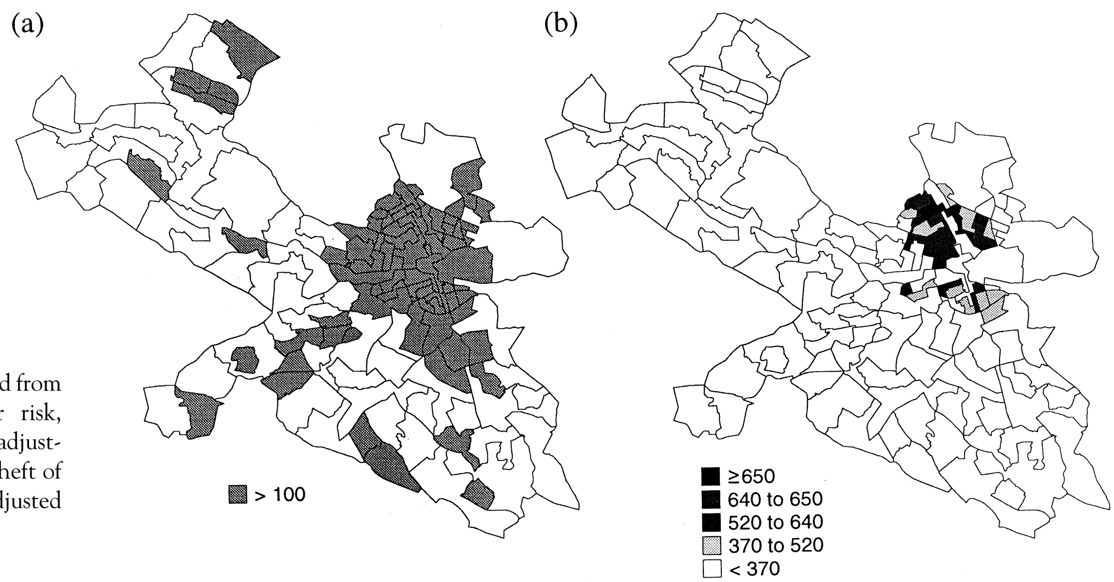

Figure 9. (a) Theft of and from cars—areas with higher risk, Stockholm, 1998, Bayes adjustment O(I) > E(I). (b) Theft of and from cars, Bayes-adjusted SOR, Stockholm, 1998.

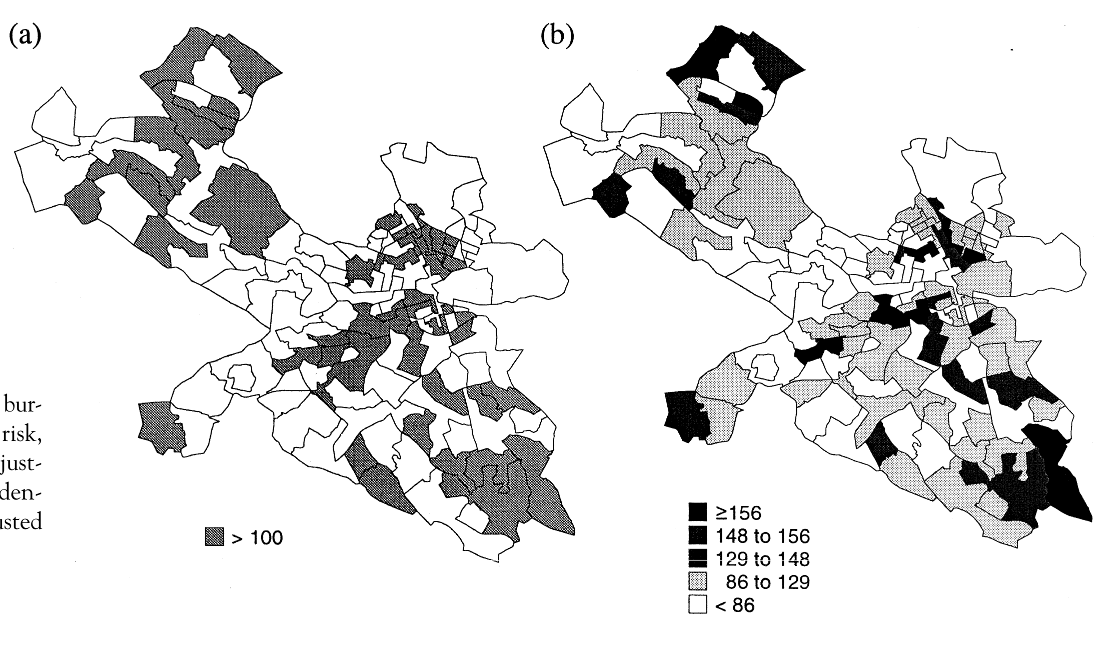

Figure 10. (a) Residential burglary—areas with higher risk, Stockholm, 1998, Bayes adjustment O(I) > E(I). (b) Residential burglary, Bayes-adjusted SOR, Stockholm, 1998.

Detecting Spatial Clusters of High SORs

The Getis-Ord Statistic. The objective now is to analyze the spatial variation of offences across the study area in order to detect statistically significant clusters of high Bayes-adjusted SORs. Clusters of high values are detected using a local Getis-Ord statistic of spatial concentration G(i)* (Getis and Ord 1992). Inference is based on a standardized z-value computed by subtracting the empirical G(i)* from the expected mean and dividing the result by the expected standard deviation under the null hypothesis of a random distribution of SORs. The local Getis-Ord statistic provides a criterion for identifying clusters of high SORs, indicating the presence of significant local spatial clusters. G(i)* is given by the following formula:

$$G(i)^* = \sum_j w_{ij}\,(d)x_j / \sum_k x_k; \qquad (2)$$

where w_{ij} (d) = 1 if the distance between case j and case i is less than or equal to d and 0 if the distance between case j and case i is greater than d.

The radius d is topological distance, or lag. Lag 1 means the calculation takes the areas which have first-order adjacency with any selected area; lag 2 means that the calculation takes not only the first adjacent areas but also those adjacent to the lag 1 areas; and so on for lags 3, 4, etc. If a cluster is small and exists only when taking first nearest neighbor areas, it should disappear—in the sense of no longer being statistically significant—when the lag order is increased. The furthest lag used in this study was the third order. Undertaking analysis at different lags amounts to testing for different spatial scales of clustering.

A positive and significant z-value indicates spatial clustering of high SORs, whereas a negative z-value indicates spatial clustering of low SORs. It is important to note that the inference theory for the local Getis-Ord test is only strictly valid if no global tendency to spatial concentration or autocorrelation exists. Results for the global Getis-Ord statistic (see Appendix 3) show that this assumption does not hold for any of these offences. The effect of global clustering on the performance of the Getis-Ord statistic has been noted; while it does not invalidate the technique, the results reported here should be interpreted with caution.

A conservative Bonferroni bound procedure was used to assess significance in order to take account of the effect of multiple testing. It is a conservative test criterion (that is, there is an increased risk of a type II error) because the 119 tests, one per area, are not independent, since they use overlapping subsets of the data. In the context of these circumstances, and using an overall α significance level of 0.05, the significance level for each individual test score was set to 0.05/119 or 0.00042. Maps were created showing areas with clusters of high SORs, which are statistically significant ($p \leq 0.00042$) for the study area. The resulting clusters are discussed below.

Discussion of Maps and Tests for Clustering. The following discussion of the results has two levels of analysis. The first level refers to results on the spatial variation in the Bayes-adjusted SORs as discussed in the section on that topic above (Figures 8–10). These results are compared with Wikström's findings (1991). The second level refers to results based on the Getis-Ord test (see previous section), which describes larger-scale patterns in the data, namely geographical clusters of areas with high Bayes-adjusted standardized offence ratios. In contrasting standardized ratio maps, it is usual to pivot the shading on 100, where E(i) = O(i). In this case, the Bayes-adjusted SOR maps also need to be comparable to Wikström's rate maps.

Was the increase in vandalism that occurred during the 1990s associated with a change in its geography? Did it continue to be mostly concentrated in the inner city? Comparing Figures 2 and 8, it appears that the geography of vandalism may have changed to some degree since the 1980s. Wikström (1991) noted the marked concentration of this type of offence in the inner city, but also in the area to the northwest of Stockholm City and in a few southern parts (such as parts of Spånga-Tensta) (Figure 2). It appears that in the 1990s the spatial pattern shown in Figure 8a has become more scattered, extending to other peripheral areas such as those in the southern, southwestern, and western areas of Stockholm (such as Hagsätra-Rågsved, Hammarby, and Vällingby). However, the evidence of Figure 8b displays close correspondence with Figure 2 and the areas with high SORs of vandalism are still geographically concentrated in the inner city (Figure 11). Figure 11 shows the statistically significant clusters of vandalism using the different scales of cluster detection. Note that at the third lag, no cluster appears, which indicates the spatially concentrated character of the clusters.

Theft of and from cars also showed a marked concentration in the inner city in the 1980s (Wikström 1991). It appears that the inner-city area, which had a high relative risk of car-related thefts in the 1980s (Figure 3) still had a high level in the 1990s (Figure 9). The evidence of Figure 9a suggests that some new areas with high levels of relative risk may have emerged in the 1990s, especially in Southern Stockholm (e.g., parts of Hammarby and Årsta). Figure 12 shows the areas with a geographical

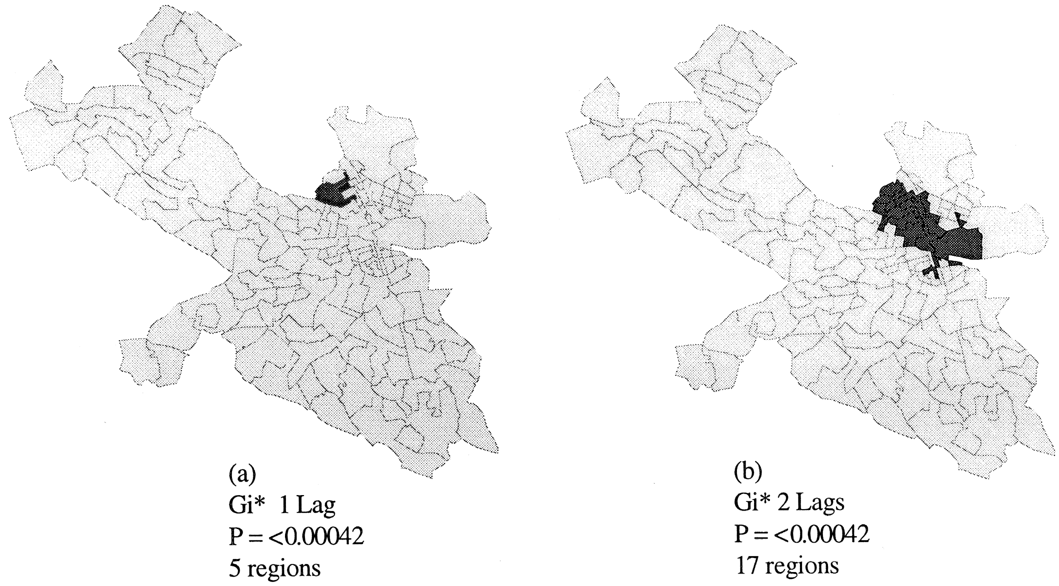

Figure 11. Clusters of vandalism using G(i)*, Stockholm, 1998.

concentration of high relative risks of car-related thefts in Stockholm City, based on the different cluster criteria. Using first-order adjacency, Figure 12a shows that only a small area of the city center, mostly the commercial area, has a statistically significant concentration. In Figures 12b and 12c, almost the whole inner city comprises a statistically significant cluster of car-related thefts, with two other small clusters appearing in the southern and western parts of the city. Some evidence exists that in the 1990s there was a weaker association between the geography of vandalism and the geography of car-related crime than that found in the 1980s. New clusters of car crime, unrelated to clusters of vandalism, are appearing away from the city center.

Residential burglary has the most scattered pattern of high relative risk. As Figures 4 and 10 reveal, several areas retained a high relative risk of residential burglary into the 1990s (mostly in the southern areas, e.g., parts of Farsta and Enskede). Some areas have seen their risk increase (e.g., Akalla) while other areas appear to have become less vulnerable (e.g., parts of Bromma). No statistically significant clusters were identified for residential burglary, indicating that areas with high rates of residential burglary are more scattered over Stockholm City than is true for the other two types of offences.

Modeling Offence Rates

To what extent can socioeconomic variables explain the variation in relative risk for Stockholm City? The ordinary linear regression model has been used to try to explain the relationship between these variables:

$$Y = X\beta + \varepsilon \tag{3}$$

where Y is the dependent variable (Nx1 vector), X is an Nxp matrix with N (= 119) cases on p explanatory (including the constant term) variables, β is a px1 vector of regression coefficients, and ε is random error with mean 0 and variance $\sigma^2 I$.

The dependent variables in this study are the three Bayes-adjusted standardized offence ratios. Drawing on the existing literature, a set of variables has been chosen as possible explanatory variables. (For a further description of the variables, see Appendix 1). The explanatory variables include:

1. percentage of inhabitants born abroad
2. percentage of unemployed inhabitants aged 18–24
3. percentage of unemployed inhabitants aged 25–64
4. average income per economically active member of the population (16–64)
5. percentage of inhabitants who moved into the area during 1996–1997
6. percentage of inhabitants who moved out of the area during 1996–1997
7. percentage of multifamily houses
8. percentage of single-family houses
9. percentage of households receiving social benefits

Findings from previous Swedish studies on crime patterns and also from North American and British case studies (e.g., Maguire and Benet 1982; Roos 1986; Wik-

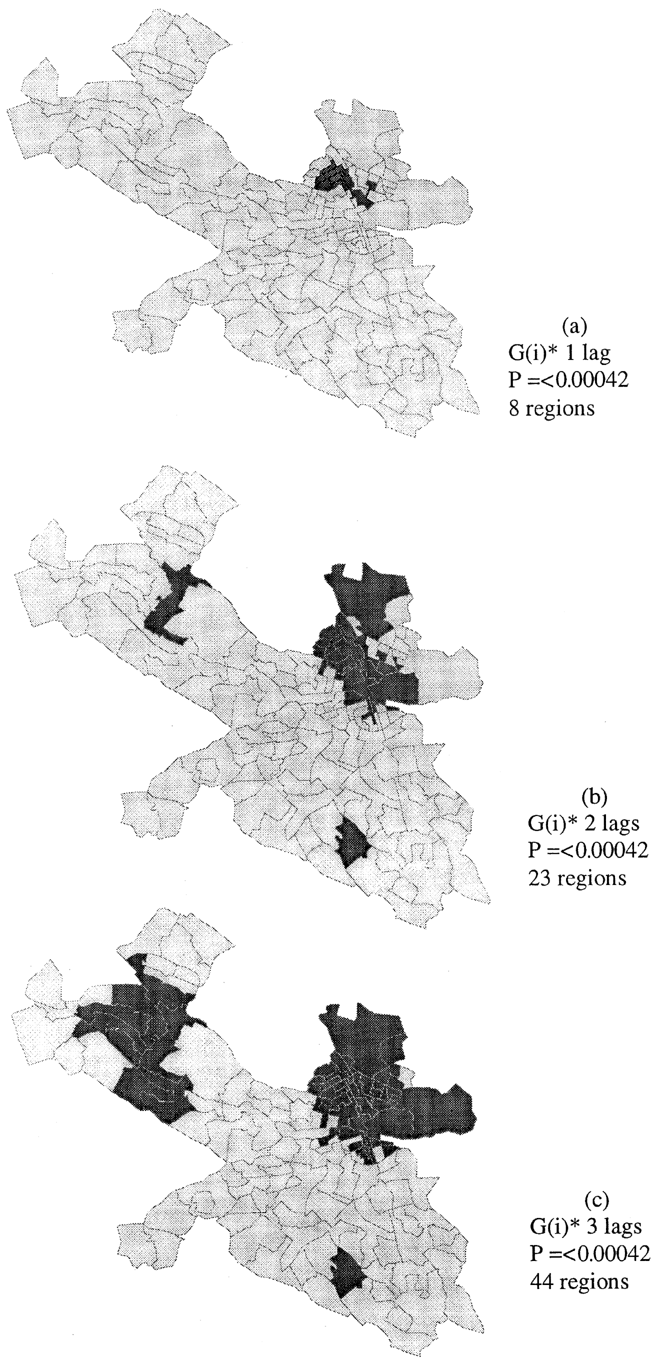

Figure 12. Clusters of theft of and from cars using G(*i*)*, Stockholm, 1998.

ström 1991; Evans 1992; Wiles and Costello 2000) were used as a background for the choice of explanatory variables. The above socioeconomic variables were chosen because they are indicators of the key variables underlying the variation in offence levels: community change, social instability, and economic deprivation.

Two additional variables were included in the model in order to estimate regional effects. The first was a dummy variable that indicated whether an area (*i*) was part of the inner city (D(*i*) = 1) or not (D(*i*) = 0). The inner-city boundaries were established based on the official spatial definition of the inner city (RTK 1994), which was then related to the spatial units produced by the region-building process. Figure 7 shows the inner city defined in terms of the spatial units used in this analysis. The second additional variable was the distance from the center of Stockholm's CBD to every other area, as defined by each area's centroid. These variables were inserted as extra columns in the database used for running the regression analysis:

10. Dummy variable to distinguish between inner city and outer city areas
11. Distance between each area's centroid and Stockholm's CBD

The regression analysis was also implemented in SAGE, because SAGE has regression-modeling capabilities that are appropriate for spatial analysis.[1] Other software packages such as SpaceStat can also be used for this form of modeling (Anselin 1988).

Vandalism

Model results show that only the percentage of unemployed inhabitants age 25–64 and the dummy variable identifying the inner city were statistically significant in explaining the pattern of relative risk for Stockholm City. In both cases, the signs of the regression coefficients are as expected. The model explains just over 40 percent of variation in the rate of vandalism. Figure 13 shows the map of the large positive residuals.

The more central the region, the higher the relative risk of vandalism is present in it. Most vandalism and violence occurs in and around public entertainment areas, such as restaurants, discos, pubs, theatres, and museums (compare Figure 13 with Figure 5). In the case of Stockholm, these sites are heavily concentrated in the inner city. Outer-city areas with a high percentage of unemployed people also have a high risk of vandalism. This may indicate a lack of social stability or a high level of social disorganization (Shaw and McKay 1931, 1942). These findings correspond with those found by Wikström (1991) and described above in the section on local geographies of vandalism.

Theft of and from Cars

The findings of this study show that the relative risk of car-related thefts is explained by housing type and loca-

Y = Vandalism

Y = 12.060 + 22.046x_3* + 275.707x_{10}**
(0.290) (2.331) (8.973)
(t-values in brackets)

* Significant at the 5% level
** Significant at the 1% level

R^2 X 100 = 41.2%
R^2 (adjusted) X 100 = 40.2%

Shapiro-Wilks normality test 0.903 Prob 0.000
Moran's I on residuals: -0.010 Prob 0.861205

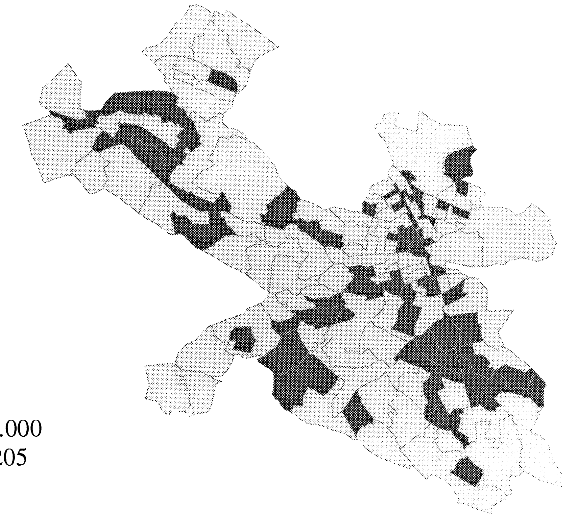

Figure 13. Positive residuals of the multiple ordinary linear regression for vandalism.

tion (Figure 14) and corresponds closely with those found by Wikström (1991) as described in the section above on local geographies of theft of and from cars. The inner city has higher levels of car-related thefts than the rest of Stockholm. "Taking without the owner's consent"—TWOC—is a common offence committed by youths, and there seems to be a particularly high relative risk of it in the inner city. Thefts from cars in the inner city can also be associated with other types of small offences committed by drug addicts.

The model suggests that the more multifamily housing (flats), the higher the relative risk of car theft and theft from cars (Figure 14). According to Wikström (1991, 231–32), who found similar results, "the differences in guardianship between multifamily and single-family houses may explain the pattern of such offences in Stockholm. The guardianship of cars parked in single-family houses, often at the house lot or in a garage, may be considered to be higher than in other areas where cars are mostly parked in public spaces." The lowest relative risk of thefts of and from cars tend to be found in areas where either formal or informal surveillance is greatest—that is, in areas with single-family houses.

Figure 14 shows the positive residuals that indicate the areas where the offence pattern is underpredicted by the regression model. If the map of residuals is compared with Figure 6, several of the areas that show positive residuals can be seen to be high-income areas, such as central, western, and southern parts of Stockholm. This may be an indication of the emergence of a new element in the geography of car-related theft since the 1980s: increased rates of car crime in relatively affluent areas.

The value of the Moran's I test on the residuals suggests a problem of residual spatial autocorrelation. A spa-

Y = Theft of and from cars

Y = -33.998 + 1.718x_7** + 333.448x_{10}**
(-0.778) (3.330) (13.088)
(t-values in brackets)

**Significant at the 1% level

R^2 X 100 = 68.8%
R^2 (adjusted) X 100 = 68.3%

Shapiro-Wilks normality test: 0.969 Prob 0.072
Moran's I on residuals: 0.096 Prob 0.0560762

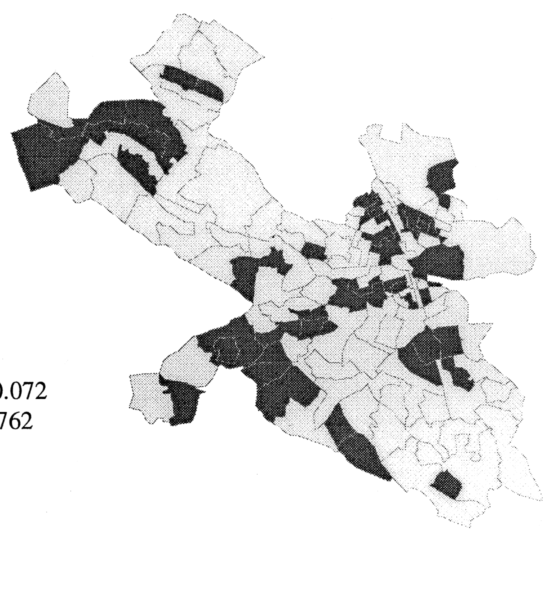

Figure 14. Positive residuals of the multiple ordinary linear regression for theft of and from cars.

Table 3. Fitting Spatial Error Model: Theft of and from Cars

Dependent variable: Theft of and from cars

$R^2 \times 100 = 65.3\%$

Maximum Likelihood Estimation

Variable	*Coefficient*	*Standard Deviation*	*Z-value*	*P*
lambda	0.229	0.123	1.860	0.063
constant	34.537	47.249	−0.731	0.465
X7	1.776	0.540	3.287	0.001
X10	321.871	28.800	11.176	0.000

Shapiro-Wilks normality test: 0.970 Prob 0.088

Diagnostics for spatial error dependence: Test: LR, $df = 1$, Value = 2.674, $P = 0.102$

Note: LR denotes likelihood ratio. *df* denotes degrees of freedom. *P* denotes probability of retaining the null hypothesis.

tial error model is fitted in order to avoid inferential errors that can be created as a result of possible model misspecification (Haining 1990). The results from the spatial error model suggest that the earlier findings are unchanged, although parameter estimates are slightly adjusted. In Table 3, "lambda" refers to the autocorrelation parameter in the spatial error model (Haining 1990).

Residential Burglary

Model results suggest two contrasting components to the burglary map. High relative risks of residential burglary appear to occur both in the more affluent areas and in the more deprived areas (Figure 15). The level of explanation attained by the model is poor (around 20 percent), but this may in part be due to the dichotomous nature of the underlying pattern.

The results from the regression model show that the higher the income, the higher the relative risk rate of residential burglary. This fits into the Swedish pattern for this type of offence, as noted by Wikström (1991), which supports the view, articulated above, that an area's attractiveness affects its rate of residential burglary. Another variable that can be associated with income distribution is the percentage of people moving in/out—that is, the population turnover. The results show that the lower the population outflow, the greater the residential burglary rate. Such relative population stability might be expected in areas with relatively high income levels, high levels of house ownership, and high numbers of single-family dwellings. The results also point to another component to the offence pattern: the higher the percentage of multifamily houses and the higher the percentage of people who are born abroad, the higher the rate of residential burglary.

These two components to the pattern in Stockholm

Y = Residential burglary

$$Y = 45.479 + 1.200x_1^{**} + 0.026x_4^{*} + (-3.842)\,x_5^{**} + 0.905x_7^{**}$$

(2.268) (3.032) (2.224) (-2.774) (4.256)

(t-values in brackets)

* Significant at the 5% level

** Significant at the 1% level

R^2 X 100 = 20.9%

R^2 (adjusted) X 100 = 18.1%

Shapiro-Wilks normality test 0.926 Prob 0.000

Moran's I on residuals: 0.024 Prob 0.431869

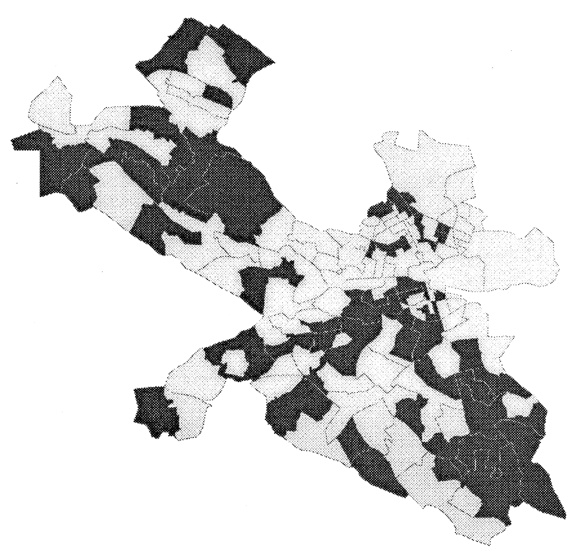

Figure 15. Positive residuals of the multiple ordinary linear regression for residential burglary.

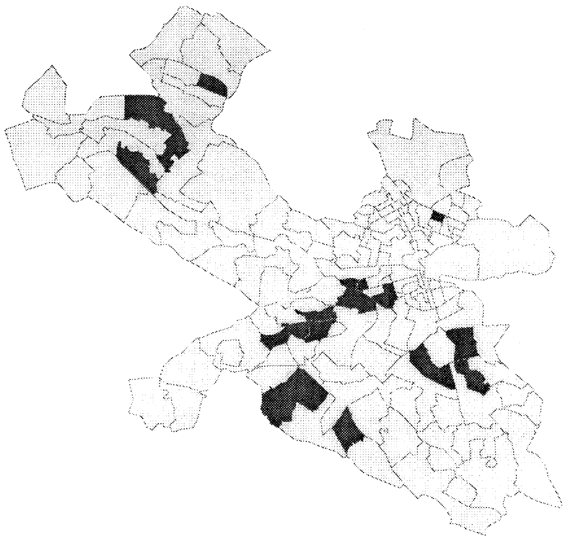

Figure 16. Positive residuals of the multiple ordinary linear regression for vandalism and theft of and from cars.

are consistent with earlier findings in other countries. Wealthy areas have high vulnerability to residential burglary because they provide attractive targets for offenders. At the same time, multifamily housing areas have high rates of residential burglary because they may be located close to where the offenders live. Regions with high relative risks of residential burglaries that are not explained by the model (Figure 15) include the inner city and a significant part of southern and western Stockholm City, both high- and low-income areas.

Figures 16 and 17 show only the areas with positive residuals from the linear regression model. One characteristic these areas share is that they are almost all low-income areas. In Figure 17, more than half of shaded areas are composed of low-income areas. This might indicate that low-income areas have a special dynamic that makes analysis of their offence patterns a difficult task. High turnover rates associated with rapid changes in demography comprise two examples of such complexity that are closely linked with the role of community change in explaining offence patterns (Bottoms and Wiles 1995).

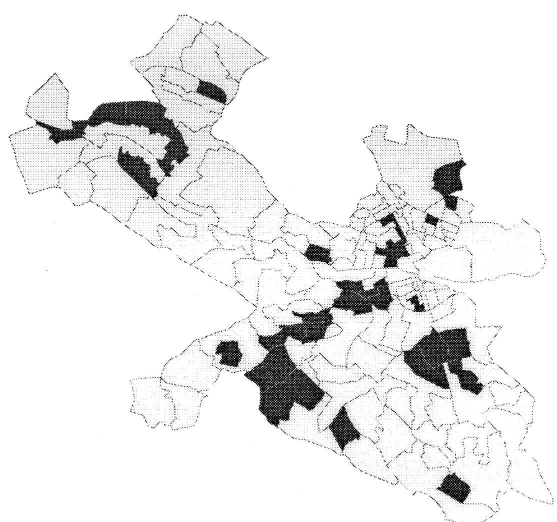

Figure 17. Positive residuals of the multiple ordinary linear regression for vandalism, theft of and from cars, and residential burglary.

Final Considerations

Since the early 1980s, Stockholm has become a more international and more segregated city. New patterns of mobility have been imposed with the arrival of, for instance, out of town retailing. Renewal programs have stimulated population turnovers, and there are indications of an accentuated gentrification process in the inner city areas. All these changes are expected to affect offence patterns.

The results reported here suggest no dramatic changes in the geographies of vandalism, theft of and from cars, and residential burglary rates since the findings of Wikström (1991). However, there have been shifts in terms both of geographical patterns—notably in relation to the outer areas of Stockholm—and of the association of relative risks with underlying socioeconomic conditions.

Vandalism and theft of and from cars take place mostly in the inner city, in which administrative, commercial, and cultural activities are still located. SOR and cluster maps show concentrations around the CBD and other small areas in the south and west of Stockholm. Although these offences still have a concentrated geography, they may have become more scattered than they were in the 1980s. Outside the inner city, areas with traditional social problems are the main targets, but new high-risk areas have also emerged. High risks of theft of and from cars are now seen in more affluent areas, perhaps because of declining levels of guardianship or because offenders are themselves more mobile.

The risk of residential burglary is relatively high in several areas in southern, western and central areas of the city. However, residential burglary is no longer concentrated in the more affluent areas of Stockholm. Results here suggest the risk of burglary has increased significantly in more deprived areas characterized by multifamily houses and residents who were born abroad. This may signal that burglary in Stockholm is increasingly being conducted under two different scenarios: burglary in affluent areas is often seen as the outcome of deliberate behavior based on target attractiveness, while burglary in deprived areas, close to where offenders live, is understood as an opportunistic activity. The routine activities of motivated offenders in neighborhoods close to where they live enables them to identify opportunities as they arise. These opportunities may stem from an absence of capable guardians in the immediate area and/or ease of physical access. This new component of the pattern coincides with findings elsewhere and links to the sorts of economic and social transformations occurring in many large cities in Europe and North America. On the other hand, and less interestingly, it could be the result of incorporating burglaries of attics and cellars into the data on residential burglary, as burglary in cellars seems to be related mostly to areas dominated by multifamily houses. In either event, with two such different processes potentially underlying the geographical distribution of burglary, attention may need to be paid to constructing other model specifications.

The incorporation of new variables into these regression models is essential if their explanatory performance is to be improved. In the specific case of theft of and from cars and vandalism, information about variations in land use (e.g., the location of public transport stops and the mixture of different types of land use) might improve model performance. Other areas of interest include the type of tenancy and the incorporation of information on crime prevention measures, such as Neighborhood Watch and other activities directed specifically towards curbing juvenile delinquency.

In the case of residential burglary, other variables may help to explain the pattern of high relative risk (Figure 15). It is known that areas with high relative risks of residential burglary tend to be located close to areas with high offender rates in the outer city and parts of the inner city (Wikström 1991). This argues for the inclusion of aggregate data on where offenders live as an explanatory variable in the regression model. An analysis of types of offenders could also explain contradictory spatial patterns of offences, helping to understand the differences between young, opportunistic amateurs and older, deliberate, professional offenders.

A further variable that would help to explain residential burglary is housing ownership, rather than housing type. The variables of housing type and housing ownership are strongly correlated in Sweden, but they are not the same. Differences between rental housing (public housing and private housing companies) and owner-occupied housing are expected to explain patterns of offences (Wikström, Torstensson, and Dolmén 1997). Data on the proximity of residential areas to communications links such as railways, motorways, and underground stations could improve both models for vandalism and car-related theft and those for residential burglary.

The findings reported in this article are based on the implementation of a two-stage methodology for constructing reliable maps of relative risks where spatial variation is not an artifact of the data. The methodology first required the construction of a spatial framework in which each area had a minimum population size and population size differences were constrained. The area with the largest population had only three times the population of the area with the smallest population, as compared with a nearly thirty-fold order of difference in the original spatial units (basområde). Population was used for the criterion because burglary rates use population for the denominator. Although the other two offence rates use area in their denominator, population size provides the best compromise for making comparisons across the different offences. At the second stage, rates were then further modified by the adoption of a Bayesian adjustment procedure that shrinks rates for areas with small populations towards the rate for Stockholm as a whole. This is recommended because, while such rates have low bias, they also have low precision.

Analysis involved inspecting the risk maps to identify areas with high relative risks and, through use of the Getis-Ord statistic, testing for different scales of spatial clustering of high SORs. The final stage employed spatial regression modeling in order to identify covariates that would describe the variation in relative risk. The modeling methodology was limited to fitting the linear regression model, including a spatial error term only in the case of thefts of and from cars in order to deal with residual autocorrelation arising in the original specification. Wilkström's (1991) model does not make explicit the role of spatial relationships between areas with different socioeconomic characteristics in understanding variations in offence rates. Further work in this area will, it is hoped, give a clearer indication of the types of spatial regression model specifications that would be appropriate (see, e.g., Anselin 1988; Haining 1990).

Appendix 1: Description of the Socioeconomic Explanatory Variables (Xs)

Variables	Calculated Based on
Percentage of inhabitants born abroad	RTK's definition, which includes both foreign citizens and Swedish citizens who are born abroad
Percentage of unemployed inhabitants aged 18–24 (not including those in trade union education-ALU or labor-market training)	The total population of each area aged 18–24
Percentage of unemployed inhabitants aged 25–64 (not including those in trade union education-ALU or labor-market training)	The total population of each area aged 25–64
Average income per economically active member of the population (16–64), yearly	Average income per economically active member (aged 16–64) of the population of each area
Percentage of inhabitants who moved into the area during 1996–1997	The total population of each area
Percentage of inhabitants who moved out the area during 1996–97	The total population of each area
Percentage of multifamily houses (multistory houses)	Total number of households, which corresponds roughly to the total number of dwellings in each area
Percentage of single-family houses (detached houses)	Total number of households, which roughly corresponds to the total number of dwellings in each area
Percentage of households receiving social benefits	Total number of households in each area

Appendix 2: SAGE—Spatial Analysis in a GIS Environment

SAGE—Spatial Analysis in a GIS Environment—is a software package for interactively studying area-based data. SAGE can be used for analysis of spatial data, with emphasis on rapid interactive visualization of data supported by a suite of cartographical, graphical, and analytical tools as a result of integrating spatial statistical analysis (SSA) techniques with a state-of-the-art GIS, ARC/INFO.

SAGE has been implemented on Sun workstations with the Solaris 2.5 operating system. It also requires ARC/INFO 7.0 with Arctools and Motif 1.2 shared library. SAGE has been implemented as an application of client-server technology. It is composed of two separate but cooperative programs, a client program and a server program. The server program is based on ARC/INFO, while the client is made from a set of SSA tools. The server provides services; the client is the consumer. SAGE requires two working directories as its working space, one for the server and one for the client, to manage temporary files.

The software is designed to handle area-based data sets (although it is possible to use point data). Each area, together with its associated attributes, is considered as a single object by SAGE, and is identified internally by a unique integer, an object identifier.

In this case study, all data for a SAGE view was stored in a single coverage, with the attributes held in a single Polygon Attribute Table (PAT). It was also possible to attach additional attributes held in separate INFO tables to this PAT using the ARC/INFO RELATE mechanism.

Regarding data manipulation, SAGE allows the user to import data from ASCII files as new attributes. It also offers tools to export attributes and weights matrices to ASCII files so that they can be used in other software packages. SAGE provides tools that create weights matrices in predefined forms by using feature attributes, but it also allows the user to modify predefined weights matrices and build weights from scratch. Finally, SAGE provides tools allowing the user to perform a set of arithmetic and statistical computations on the original data and to save results as new attributes.

Data visualization in SAGE can be done through three components: a map window (map), a spreadsheet-like window (table), and a graph window (graph). A map shows the shape of an object, while a row in the table window presents all active attributes of an object. A point or bar gives a view of the partial properties of an object, such as an item in a histogram, an XY scatter, an XW scatter, or a boxplot.

For further information about the functionality and architecture of the system, see Haining, Wise, and Ma (1996, 2000). A copy of the software can be freely obtained from the website, http://www.sheffield.ac.uk/~scgisa.

Appendix 3: Values of Tests for Global Spatial Concentration and Autocorrelation

Based on the results of Bayes-adjusted SOR, the global Getis-Ord test for spatial concentration and Moran's *I* test for spatial correlation have been applied. The values of the Moran's *I* indicate positive spatial autocorrelation. The Moran's *I* is positive when nearby areas tend to be similar in attributes; it would be zero if the attribute values were arranged randomly and independently in space.

Values of tests for global spatial concentration and autocorrelation:

	Global Getis-Ord[a]	Global Moran's I^a
Vandalism	0.081	0.897
Theft of and from cars	0.070	0.927
Residential burglary	0.047	0.869

[a] All values are significant at the 1 percent level.

Acknowledgments

The research for this article was undertaken while Vânia Ceccato was a visiting researcher at the University of Sheffield, England. The authors would also like to express their thanks to USK, the Stockholm Office of Research and Statistics—especially Åke Östman—and the Stockholm Police Authority for providing the data used in this analysis.

Note

1. For more detail about regression models in SAGE, see Ma, Haining, and Wise (1997) and Haining, Wise, and Ma (2000).

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